

**Draft Recommendation for  
Space Data System Standards**

**RADIO FREQUENCY AND  
MODULATION SYSTEMS—  
PART 1: EARTH STATIONS  
AND SPACECRAFT**

**DRAFT RECOMMENDED STANDARD**

**CCSDS 401.0-P-17.1**

**PINK SHEETS**

**May 2007**

**Earth Stations and Spacecraft**

**2.4.12A MAXIMUM PERMISSIBLE PHASE AND AMPLITUDE IMBALANCES FOR SUPPRESSED CARRIER (BPSK/(O)QPSK/GMSK) RF MODULATORS FOR SPACE-TO-EARTH LINKS, CATEGORY A**

The CCSDS,

considering

- (a) that suppressed carrier modulation (PSK) is recommended by CCSDS [401 (2.3.2) B-1] for spacecraft telemetry transmissions in the 2 and 8 GHz bands when residual carrier modulation would exceed PFD limits on the Earth's surface;
- ~~(b) that the presence of unwanted discrete spectral lines in the received spectrum may degrade the receiver's performance;~~
- ~~(c) that phase and amplitude imbalances in the modulated RF carrier, caused by imperfections in the PSK modulator, contribute to the generation of a spurious spectral line at the carrier's frequency which can be detrimental to the performance of a PSK system and which may exceed PFD constraints;~~
- ~~(d) that a phase imbalance of less than 2 degrees and an amplitude imbalance of less than 0.2 dB will result in a carrier suppression of between 25 and 42 dB;~~
- ~~(e) that for near Earth missions where one can have excessive data margin, the degradation due to the cross talk caused by the phase and amplitude imbalances in a balanced QPSK system can be tolerated up to 0.4 dB;~~
- ~~(f) that although the phase and amplitude imbalances in a balanced QPSK modulator contribute to the generation of cross talk between channels which can be detrimental to the system performance, the actual limiting factor is the PFD constraints for near Earth missions where excessive data margin can be available;~~
- (b) that Filtered OQPSK ( $BT_s = 0.5$ ) and GMSK ( $BT_s = 0.25$ ) modulations are recommended by CCSDS [401 (2.4.17A) B-1] for high rate telemetry in the 2 and 8 GHz Category A bands and in the 8 GHz EESS band;
- (c) that, for a balanced quadrature modulation, the phase and amplitude imbalances in the modulated RF carrier as well as the phase imbalance between channels contribute to the generation of cross-talk between channels through either a failure of maintaining the inter-channel orthogonality or an imperfect carrier tracking, which can be detrimental to the system performance;
- (d) that a phase imbalance of less than 5 degrees and an amplitude imbalance of less than 0.5 dB should result in acceptable performance degradations for near-Earth missions;

recommends

- ~~that the modulator's phase imbalance shall not exceed 2 degrees and the amplitude imbalance shall not exceed 0.2 dB in a suppressed carrier RF modulation system, provided however that the carrier suppression shall always be 30 dB or more.~~
- that the modulator's phase imbalance shall not exceed 5 degrees and the amplitude imbalance shall not exceed 0.5 dB between the constellation points in a suppressed carrier RF modulation system using BPSK, (O)QPSK, Filtered OQPSK, or GMSK  $BT_s = 0.25$ .

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**2.4.12B      MAXIMUM PERMISSIBLE PHASE AND AMPLITUDE IMBALANCES FOR  
SUPPRESSED CARRIER (BPSK/(O)QPSK/GMSK) RF MODULATORS FOR  
SPACE-TO-EARTH LINKS, CATEGORY B**

**The CCSDS,**

**considering**

- (a) that suppressed carrier modulation (PSK) is recommended by CCSDS [401 (2.3.2) B-2] for spacecraft telemetry transmissions in the 2 and 8 GHz Category B bands;
- (b) that Gaussian Minimum Shift Keying with  $BT_s=0.5$  is recommended by CCSDS [401 (2.4.17B) B-2] for high rate telemetry in the 2 and 8 GHz Category B bands;
- (c) that, for a balanced quadrature modulation of which the data rate and the power are the same for both In-phase (I) and Quadrature (Q) channels, the phase imbalance between channels caused by a deviation from the ideal 90-degree separation occurs when the phase shifter at the transmitter and/or the receiver is no longer operated in the linear region;
- (e) that, for a balanced quadrature modulation, the phase and amplitude imbalances in the modulated RF carrier as well as the phase imbalance between channels contribute to the generation of cross-talk between channels through either a failure of maintaining the inter-channel orthogonality or an imperfect carrier tracking, which can be detrimental to the system performance;

**recommends**

that the modulator's phase imbalance shall not exceed 5 degrees ~~peak-to-peak~~ and the amplitude imbalance shall not exceed 0.5 dB ~~peak-to-peak~~ between the constellation points for suppressed carrier systems using BPSK, (O)QPSK, or GMSK  $BT_s=0.5$ .

**2.4.20B MODULATION METHODS AT HIGH SYMBOL RATES TRANSMISSIONS FOR THE 31.8-32.3 GHz BAND, SPACE RESEARCH, SPACE-TO-EARTH, CATEGORY B**

**The CCSDS,**

**considering**

- (a) that in accordance with ITU RR S3.9, efficient use of the RF spectrum resources is required;
- (b) that the 32 GHz band is planned to become the backbone for communications with high rate Category B missions;
- (c) that the Space Research, Category B, frequency allocation at 8 GHz is 50 MHz wide, and missions with symbol rates higher than 2 Ms/s are required to utilize spectrally efficient modulation;<sup>1</sup>
- (d) that the Space Research, Category B, 32 GHz frequency allocation is 500 MHz wide, and therefore 20 Ms/s is the corresponding value for the 32 GHz band;
- (e) that GMSK ( $BT_s = 0.5$ )<sup>2</sup> is a spectrally efficient modulation with negligible end-to-end losses using an optimized receiver, making it an excellent choice for weak signal-level missions;
- (f) that short periodic data patterns can result in zero power at the carrier frequency;

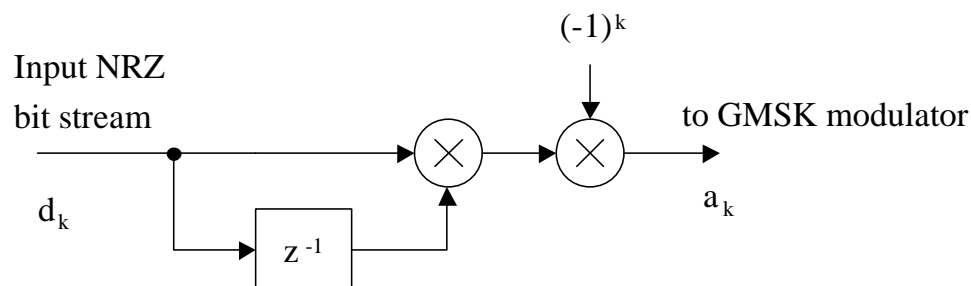
**recommends**

- (1) that GMSK ( $BT_s = 0.5$ )<sup>2</sup> be used for high data rate transmissions whenever practicable at symbol rates below 20 Ms/s and in any case for rates equal to or in excess of 20 Ms/s in communications systems operating in the 32 GHz bands;
- (2) that CCSDS agencies use a data randomizer as specified in the CCSDS Recommended Standard, *TM Synchronization and Channel Coding*, CCSDS 131.0-B-1 (or latest edition).

**NOTES:**

<sup>1</sup> See CCSDS Recommendation 401 (2.4.17B) B-2.

<sup>2</sup> Gaussian Minimum Shift Keying ( $BT_s = 0.5$ ), with precoding as in figure 2.4.20B-1. See CCSDS 413.0-G-1.



**Figure 2.4.20B-1: GMSK Precoder**

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**2.6.8B TRANSPONDER TURNAROUND FREQUENCY RATIOS FOR THE  
31.8 — 32.3 GHz AND 34.2 — 34.7 GHz BANDS, CATEGORY B**

**The CCSDS,**

**considering**

- (a) that Category B space missions use Earth-to-space links in the 34.2-34.7 GHz band in conjunction with space-to-Earth links in the 31.8-32.3 GHz band;
- (b) that many of these space missions require coherency between the Earth-to-space and space-to-Earth links for the generation of navigation data;
- (c) that for space missions which require coherency, a Transponder Turnaround Frequency Ratio (TTFR) that provides a maximum number of coherent channels must be defined;
- (d) that for reasons of standardization, of the on-board receiver design, a TTFR should be chosen in such a way as to conserve 3344 as the denominator of the ratio for the 34 GHz uplink / 32 GHz downlink system;<sup>1</sup>
- (e) that an odd number is selected as the uplink factor (numerator of the TTFR) and an even number is selected as the downlink factor (denominator of the TTFR) to prevent downlink harmonic interference with uplink signals;
- (f) that, if the denominator of the TTFR can be factored into prime numbers  $\leq 19$ , then conventional frequency multiplying devices, followed by band-pass filters, can be implemented;
- (g) that, if the difference between the numerator and the denominator of the TTFR can be factored into prime numbers  $\leq 19$ , then conventional frequency multiplying devices, followed by band-pass filters, can be implemented;
- (h) that the number of frequency multipliers should be reduced to minimize the delay in the spacecraft receiver's closed phase-locked-loop path;
- (i) that the denominator of the TTFR should be chosen to allow maximum Voltage Controlled Oscillator (VCO), Automatic Gain Control (AGC), and Diplexer implementation flexibility;
- (j) that the denominator of the TTFR should be chosen to generate a minimum number channels that fall into the *Inter-Satellite Service* allocation in the 32-33 GHz band;
- (k) that many Category B space missions carry both X-band and Ka-band transponders and that sharing of transponder hardware and implementation simplicity are desirable;

**recommends**

that CCSDS Agencies use one of the following Transponder Turnaround Frequency Ratios, ~~of~~ 3599/3344 and 3599/3360 for Category B missions operating in the 34.2-34.7 GHz and the 31.8-32.3 GHz bands.

NOTE:

- 1. See CCSDS Recommendations 401 (2.6.7) B-1.